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A Plan for a Centralized Nursery for the State of Hawaii

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A PLAN FOR A CENTRALIZED NURSERY FOR THE STATE OF HAWAII

By Floyd M. Cossitt[1/]

SECTION I

Introduction

In June 1960, the Hawaii Department of Agriculture and Conservation requested the United States Forest Service to study forest nursery practices in Hawaii. The objective of the study was to supply information that would speed up production of trees for an expanded program of reforestation by the State.

This report describes the steps in the inquiry and the findings. It also offers recommendations which, if adopted, should result in production of the desired number of trees of satisfactory quality and at minimum cost.

At the beginning of the inquiry, in July 1960, a series of conferences was held with several principal representatives of the State Division of Forestry and Forest Service officers who were connected with the project. In these conferences several important decisions were reached to guide the project:

1. The first major decision was to concentrate as much as possible of the total production in one nursery, in order to take advantage of up-to-date mechanization. Today, commercial airlines offer fast air freight service between islands at rates that are decidedly economical for transportation of baled forest tree nursery stock.

2 Because as much as 10,000 acres may be planted annually, the second decision was to plan the nursery capacity for about 4 1/2 million trees--1 million softwood seedlings and 3 1/2 million hardwood seedlings--the site to allow for some expansion.

1/ Forester in charge of the Section of Regeneration, Division of State and Private Forestry, U. S. Forest Service, Atlanta, Georgia; temporarily assigned for this project to the Pacific Southwest Forest and Range Experiment Station. The author wishes to acknowledge generous assistance from Wayne L. Collins, Director of the Hawaii Department of Agriculture and Conservation, the staff of the Division of Forestry, Dr. G. Donald Sherman, Head, Department of Agronomy and Soils, and Dr. Oliver V. Holtzman, Assistant Plant Pathologist, University of Hawaii; J. H. Christ, Robert Malmgren, Paul Harbison, and J. B. Majure, U. S. Soil Conservation; and Dr. Robert Cushing and other members of the Pineapple Research Institute.

3. A third decision grew out of a plant quarantine regulation. Plants shipped from all islands except Maui and Molokai must have all soil washed from their roots. The conferees could not vouch that washing the roots of tree nursery stock was not harmful. Consequently, the decision was reached to grow the stock where there are no requirements to wash roots for inter-island shipment. Maui was chosen because it appeared to have better potentialities than Molokai to provide a nursery site.

In October 1960, the Division of Forestry made further inquiries into the plant quarantine question, which revealed a good possibility that forest tree nursery stock may be shipped to other islands from the Big Island without washing roots under some conditions. The Division therefore requested that the search for suitable nursery sites be extended to the Island of Hawaii. Two nursery sites have been selected and are recommended as alternatives for consideration by the Division of Forestry. One is on Maui and one on Hawaii.

Review of Present Nursery Practices

The nursery practices used in the 7 existing State nurseries have been developed over a period of about 50 years, and they were well adapted to conditions at earlier times. The two characteristics which are most immediately apparent are that tree production is based very largely on hand labor and that on each of the 5 principal islands stock is produced primarily for use on that island. Other important features are:

1. Almost all of the stock is transplanted at least once in the nursery.

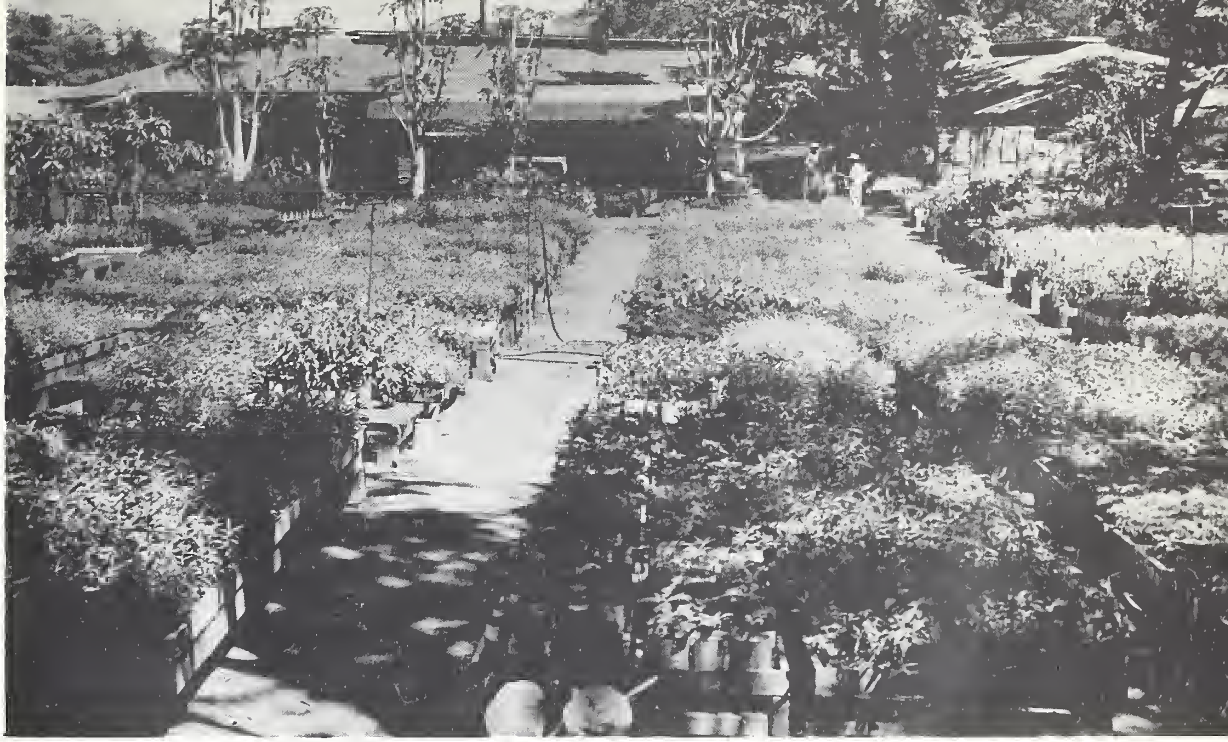
2. Much of the stock is grown in small wooden flats rather than in seedbeds, and the stock is often transported to field planting sites in the flats, rather than being lifted and baled at the nursery.

3. Relatively little use has been made of pesticides and advanced soil management techniques such as application of chemical fertilizers.

All of these characteristics contribute to higher costs of production.

Increasing costs of labor and technological advances in mechanization indicate that very material savings can be made by adopting mass production methods. Similarly, fixed costs associated with operation of several nurseries are certain to be higher than if production is concentrated in one place.

On the question of transplanting, techniques have been developed elsewhere that largely eliminate the need for this step in production. For example, in Puerto Rico, certain sections of Brazil, and in the warmer portions of the southeastern part of the mainland, where the species produced and the climate are similar to those in Hawaii, seedling stock is being successfully grown and field planted without an intermediate stage of transplanting into beds or flats.



Nursery at Division of Forestry headquarters, Kahului, Maui. This view shows eucalyptus seedlings that have been transplanted into small wooden trays which are placed on low platforms. Each flat contains 55 trees. The flats are transported to the field planting sites before the trees are removed.

Growing and transporting trees in flats does not differ essentially from widely practiced methods for a great many horticultural and crop plants. Its application to mass production of trees for reforestation, however, is unnecessary. Furthermore, it greatly increases labor costs and virtually eliminates most opportunities for mechanization.

One basic soil management technique that has been rather commonly employed in Hawaii has been to replace the soil in the flats and transplant beds with fresh soil when it becomes exhausted or infested with pests. For very small nursery units, this is a fairly satisfactory technique, but it is costly and it does not eliminate hand weeding problems. Furthermore, nematodes are becoming increasingly a major problem in production of high quality nursery stock. They must be controlled by sterilizing techniques in new soil as well as in old soil.

In contrast to soil replacement as a soil management and pest control technique, today there is a vast store of information about soil chemistry, structure, and microbiology that enables managing and improving a permanent body of soil. For mass production of trees, acres of ground are required. Soil replacement is impractical and excessively costly as well as unnecessary.

Requirements of a Nursery Site

The major requirements for an ideal site are:

1. Soil--at least 3 feet deep on slopes and 18 inches on level areas, well drained, free of rock or rock removed prior to nursery operation, not seriously erosive, and of a texture or quality that will not bake when dried nor become plastic when wetted. In addition, its acidity must be within the range of ph 4.5 to 6.8, it must have desirable fertility qualities, it must be susceptible to certain chemical modifications, and it must be free of harmful root rot organisms.

2. Climate--relatively warm but not excessively hot temperatures to promote good germination and growth; free from excessively strong winds; within a relatively low rainfall zone (30 to 80 inches annually); and with low rainfall during the principal growing season (February to October).

3. Slope--the beds (4 feet wide plus 2 feet for paths and wheel tracks) must be almost level (1 percent slope lengthwise for drainage), straight or only slightly curved, and 300 feet in length plus 25 feet at each end to turn machines around. Limited terracing perpendicular to the beds can be allowed, provided that (a) several beds can be placed on each terrace, (b) the stepdowns are small, and (c) soil is deep enough to permit the grading.

Pineapple land on Maui. Unsuited for nursery purposes because of thin, rocky soil.

Selection of a Site

Maui

A large number of areas on Maui were examined superficially and many painstakingly. At elevations below 2,000 feet, many areas have suitable soil depth and topography but soil reaction (acidity or alkilinity) is unfavorable, and climatic conditions are seriously adverse. Areas in high rainfall zones, regardless of other requirements are undesirable because of the effects of excessive rain on seedling growth. Seedling growth must be susceptible to control by artificial watering. In contrast, tracts with extremely low rainfall on the island have excessively alkaline soil and are unfavorable for this reason. At elevations above 3,500 feet, temperatures are too low for optimum germination and growth during the normal growing season, and rainfall is generally excessive. As a special case, the State nursery at Olinda should be mentioned. It is situated in a higher elevation zone and it cannot be recommended for expansion and mechanization because of excessive rainfall, low growing-season temperatures, excessive slope, and soil that is too plastic when wet.

One tract in the Makawao District (fig. 1) on property of the Haleakala Ranch Company closely approaches all of the requirements and desirable qualities that have been listed. Undoubtedly, other areas exist on Maui that would be equally suitable for a tree nursery--particularly among the intensively cultivated truck farms along the Kula road. However, these Kula tracts were considered to be unavailable. Land values are extremely high, Furthermore, to convert a small truck farm into a tree nursery would displace the owner from his source of livelihood with but poor opportunities for finding a substitute tract.

Preliminary inquiries have been made by members of the Division of Forestry to determine if the site on the Haleakala Ranch is available to develop for a nursery. The possibilities to obtain title or a long term lease are reported to be good.

The Haleakala Ranch tract contains 18 1/2 acres. It is believed to be capable of an annual production of from 5 million to 8 million trees. The estimated cost of initial development and permanent improvements, exclusive of land acquisition, is about $56,000. This investment is in line with similar modern nursery developments in parts of the mainland. In proportion to the potential benefits it is considered to be a very reasonable sum.

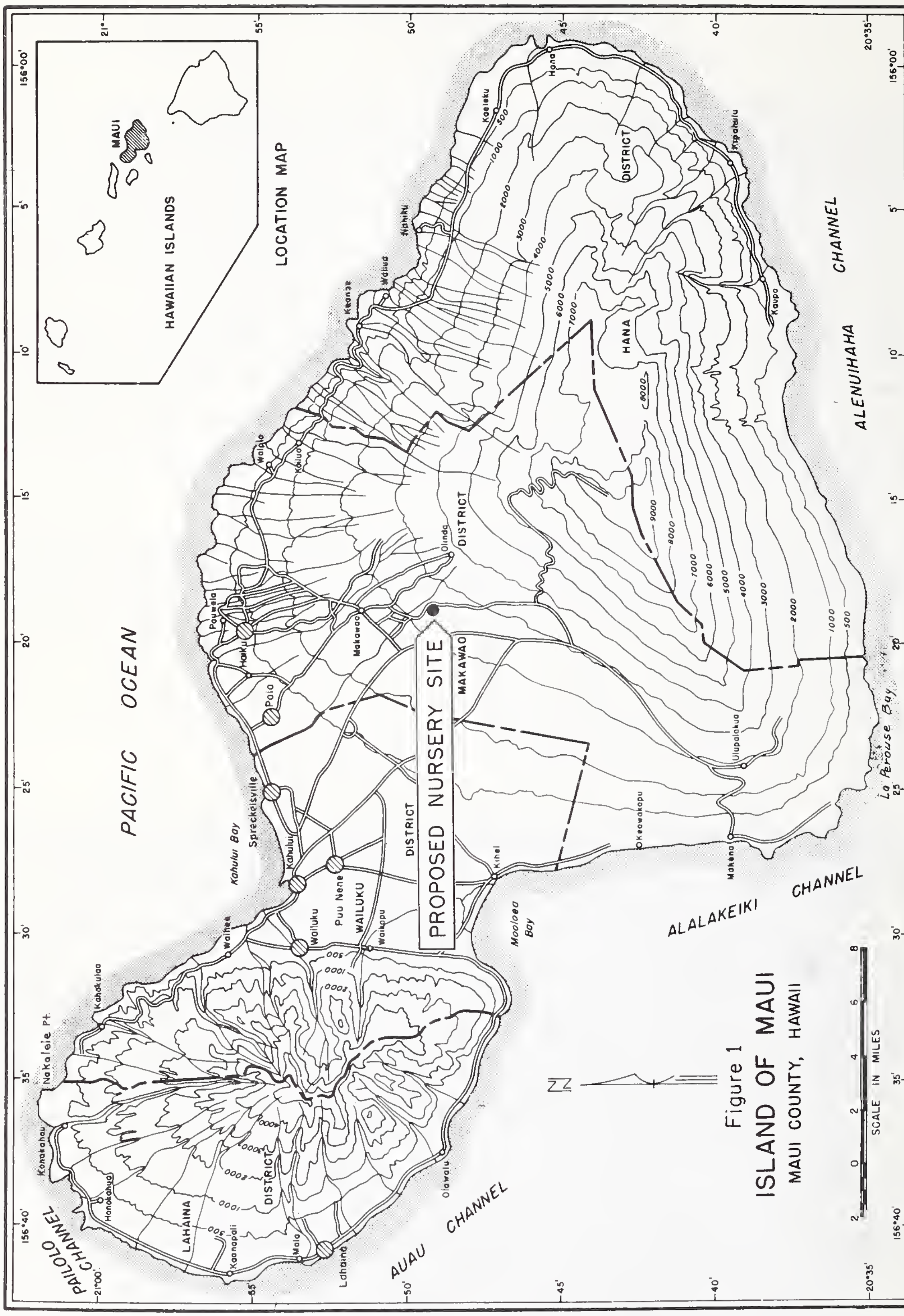


Figure 1
ISLAND OF MAUI
MAUI COUNTY, HAWAII
PROPOSED NURSERY SITE
PACIFIC OCEAN
LOCATION MAP
HAWAIIAN ISLANDS
MAUI
PAILOLO CHANNEL
AUAU CHANNEL
ALALAKEIKI CHANNEL
ALENUIHAHA CHANNEL
Kahului Bay
Maalaea Bay
La Perouse Bay
LAHAINA DISTRICT
WAILUKU DISTRICT
MAKAWAO DISTRICT
HANA DISTRICT
Nakalele Pt.
Kahakuloa
Honokahau
Honokahua
Kaanapali
Mala
Lahaina
Olowalu
Waihee
Wailuku
Waikapu
Puu Nene
Kahului
Spreckelsville
Paia
Haiku
Pauwela
Makawao
Olinda
Kailua
Waipio
Keanae
Wailua
Nahiku
Kaeleku
Hana
Kipahulu
Kaupo
Kihei
Makena
Ulupalakua
Kanaio
SCALE IN MILES
M&I. ENG. DIV. HUSARPAC 9-54

Transplanted pine seedlings in terraced beds at Olinda Nursery, Maui. Slope is too steep for broader terraces upon which tractor drawn machinery can operate.

This pasture on Maui was rejected partly because of slope (up to 12 percent) and partly because the soil is shallow and rocky.

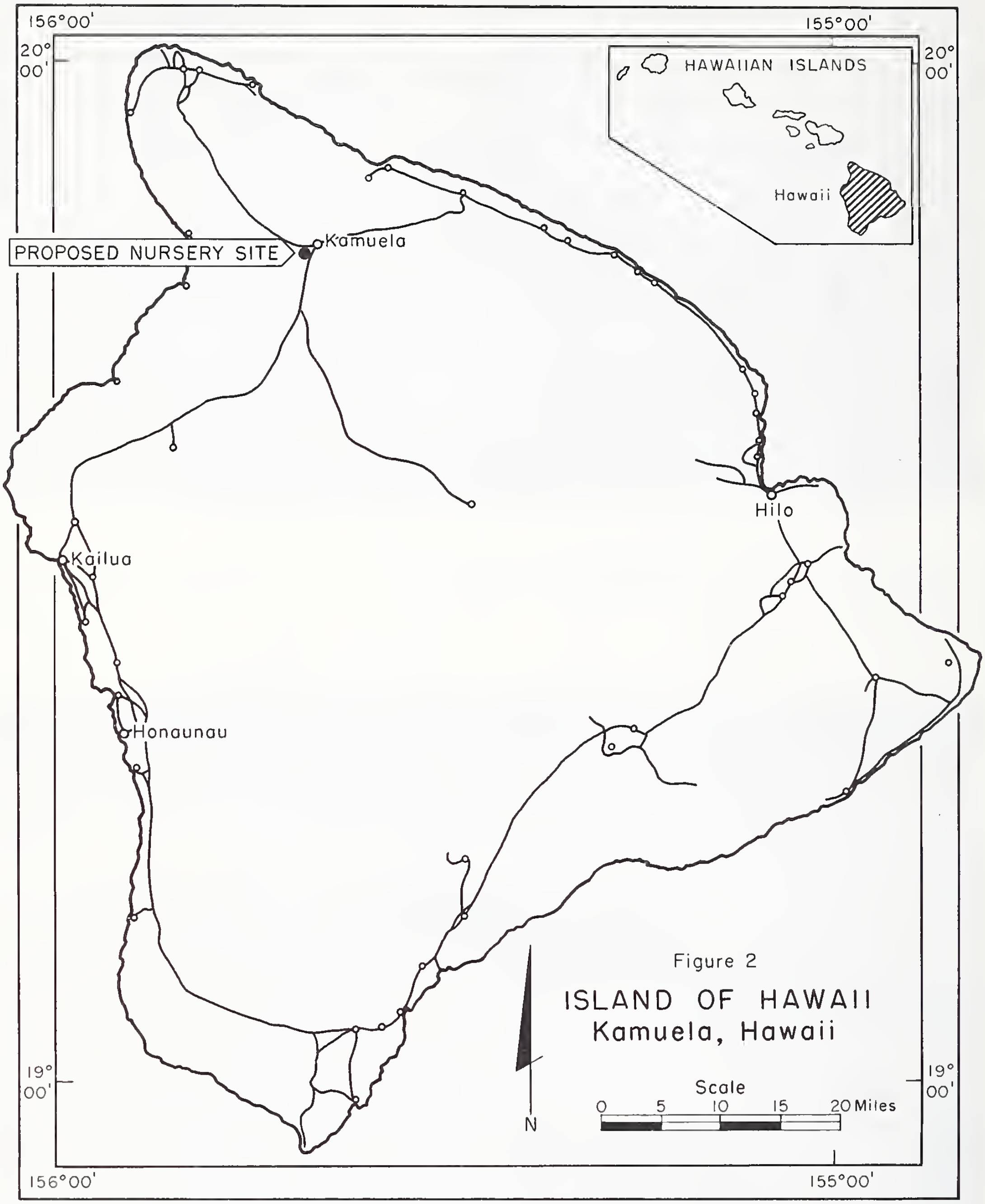


Figure 2
ISLAND OF HAWAII
Kamuela, Hawaii

Hawaii

The search for a nursery site on the Big Island was confined to the vicinity of Kamuela (fig. 2). Information received from the Soil Conservation Service indicates that some of the soils there correspond closely to those on the best site found on Maui. Weather records show that the temperature and rainfall are favorable for the desired purpose. Transportation systems and water supplies are good. Deputy State Forester L. W. Bryan designated several tracts of available land in that area which appeared to have suitable topography. A satisfactory site was chosen from among the tracts that had been suggested. Because it is owned by the State, purchase or lease is unnecessary.

The recommended tract near Kamuela is designated as Block 8 of the Lalamilo Project. It contains 15.3 acres and is capable of an annual production of 5 million to 8 million trees. The estimated cost for initial development and permanent improvements is about $50,000.

Relative Advantages of the Two Sites

In potential productivity the two sites are both favorable. The principal advantages of the Maui site are lower natural wind velocity and the presence of trees to serve as a windbreak. Only a limited amount of additional windbreak planting will be necessary. The soil characteristics are slightly more favorable. The major disadvantage is substantially higher initial construction costs. These would arise from the need to construct almost three miles of 2-inch water supply pipeline, install a reservoir, remove a timber stand, demolish several concrete ammunition shelters, and terrace the seedbed area.

The principal advantages of the site on the Big Island are that most of the field planting will be on that island, water supply with adequate pressure is available immediately adjacent, and the ground surface is sufficiently level that little grading and terracing will be required. The principal disadvantages are somewhat higher wind velocities and the need to establish a windbreak system immediately. Several years will be required to develop tight windbreaks and these may not be completely effective. A possible disadvantage of most serious nature arises from the question of the ground termite quarantine. If, either now or later, inter-island shipments of nursery stock from the site on the Big Island were prohibited, the usefulness of the nursery would be substantially reduced. In that event it could not serve as a centralized service for the whole State unless methods are found to eliminate the termites without injuring the trees.

At Kamuela irrigation pipe sizes must be larger to operate a greater number of sprinkler heads. Spacing at intervals of 40 feet on laterals 40 feet apart is quite adequate for conditions at the Haleakala Ranch site, but because of the wind at Kamuela, sprinkler heads must be spaced not more than 30 feet apart. Additional lines are also needed

on the outer edges of all seedbed blocks to compensate for drift in periods of high winds. Moreover, the irrigation system must have a minimum capacity that will permit the operation of 8 lateral lines simultaneously. Wind erosion could be serious unless ample water is available to prevent it. A shortage of water at Kamuela any time during the year could be very damaging.

Production costs at Kamuela may be 10 percent to 20 percent higher than at Haleakala Ranch because of higher wind velocities, greater consumption of water, and slightly less favorable temperatures during the growing period.

Both sites are favorably situated for inter-island air transportation of planting stock. Kamuela airport on Hawaii is practically across the road from the recommended site. The Maui nursery site is several miles distant from the nearest airport, but this airport has more flights per day.

Sections II and III of this report contain all of the information that has been obtained about the recommended tracts on Maui and Hawaii. They should be examined for further details. Section IV presents information on nursery development, operation, and estimated initial costs for development and operation.

Personnel

If the State of Hawaii elects to develop and operate a centralized nursery, a vitally important step is to recruit and train qualified personnel. Two key men are believed to be essential.

One, a staff assistant to the State Forester, is needed to coordinate the nursery and planting program. This man should be capable of directing the nursery project and should possess extensive first hand experience in nursery management. As a corollary one of his duties should be to develop annual sowing schedules based on the plans of the associate foresters on the various islands.

The other man, the nursery superintendent, should reside at the nursery and be in direct charge of all nursery work. He would, of course, receive advice and guidance from the staff assistant of the State Forester.

International Cooperation

An urgent need exists for a nursery such as outlined here to aid in training of foresters from other parts of the world, particularly from the undeveloped countries of the Far East. Climate, soils, and tree species are more comparable than those at any nursery on the mainland. A well equipped, efficiently operated nursery would serve a very useful purpose in demonstrating modern nursery techniques to foresters from less advanced nations. It would reflect credit on Hawaii and the United States and provide additional evidence of international leadership in raising standards of living beyond our own borders.

SECTION II

The Maui Site

An 18 1/2-acre tract on land of the Haleakala Ranch Company has been selected because it is the best for the purpose of any available areas that have been examined on Maui. It is located adjacent to State Road No. 377 approximately 1 mile south from the polo field. It is part of a polo pony pasture owned by the Haleakala Ranch Company.

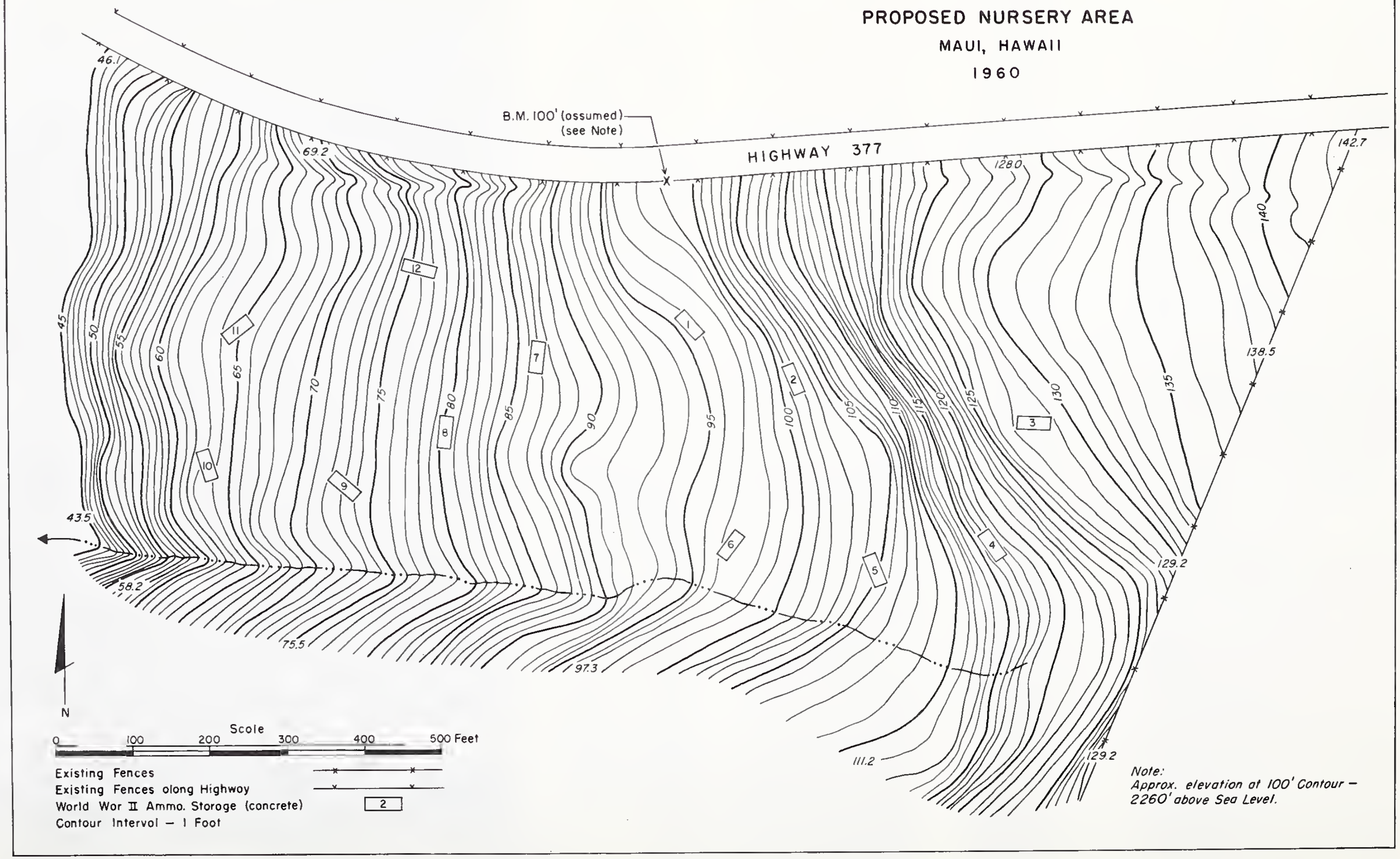
Physical Conditions

Gradients range from 1 percent to 6 percent and the slope is uniform except along the highway where sharp knolls are found (fig. 3). This part need not be used for seedbeds and it should be left undisturbed with its present stand of eucalyptus to serve as a windbreak.

On the area are twelve widely separated, concrete, ammunition shelters, 10 feet x 40 feet x 8 feet high, outside dimensions, that were constructed about 1941 or 1942. A stand of eucalyptus covers the entire tract. Some trees have been cut but the majority have resprouted. The present stand consists of understory trees that range from 5 inches to 12 inches diameter 4 1/2 feet above the ground. Larger trees are not abundant--possibly an average of 5 per acre. Stumps are numerous and appear to be practically decomposed where resprouting is absent.

Recommended nursery site on Haleakala Ranch Company property, Maui. Most of the timber and old ammunition shelters must be removed. Some of the trees could be saved for a windbreak and one of the shelters can easily be modified for cold storage of lifted and baled nursery stock.

Figure 3
TOPOGRAPHY
PROPOSED NURSERY AREA
MAUI, HAWAII
1960



The soil is tentatively classified by the Soil Conservation Service as Pane silt loam. Depths range from 44 inches to more than 60 inches. It is identical in texture to that found in the Kula commercial truck gardening area. Texturally it appears to be well suited for both conifer and hardwood seedling production.

Soil depth is entirely adequate to permit necessary grading without disturbing or exposing parent material beneath. It is the deepest soil found on any of the sites that were examined. A eucalyptus stand (more than 30 years old) has prevented the substantial soil losses that apparently have occurred on nearby cleared land.

Soil analyses by the Agronomy Department at the University of Hawaii indicate that the soil is texturally good for seedling production, and with proper management should not become sticky despite a rather high silt content. The pH ranges from 5.6 on the surface to 6.0 at subsoil depth. Water holding capacity is good. Fertilizers high in phosphorous and potash should be used in pellet form. Nitrogen should be applied largely as a top dressing in soluble form at frequent intervals. Zinc and molybdenum appear to be low. Applications of 2 pounds of zinc and 100 pounds of molybdenum per acre are recommended at intervals of about 5 years. Organic matter is now about 9 percent which, of course, will decrease appreciably with intensive cultivation.

Climate

The area is situated at an elevation of about 2,260 feet. Temperature extremes at Haleakala Branch Experiment Station about 1 1/2 miles away at approximately the same elevation show a range of 80° F. high to a low of 44° F. for the first quarter of the year. The second and third quarters are slightly warmer with a high of 86° and a low of 46°. The means are: First quarter 63° F.; second quarter 65° F.; third quarter 68° F.; fourth quarter 65° F.

Annual rainfall (19 years) at Haleakala Branch Experiment Station averages 57.7 inches, with a maximum of 92.6 inches and a minimum of 38.4 inches. Seasonal pattern shows the heaviest precipitation in the fall, winter, and spring. From May to October the mean is 1.9 inches per month. Rainfall at the proposed nursery site is believed to be materially less, but probably follows the pattern closely.

Wind velocity is relatively low, and because an effective windbreak exists no adverse effects are anticipated.

Temperature and Rainfall Patterns

Heavy rainfall, particularly during the growing season, would be extremely detrimental. Growth would be excessive, despite repeated root pruning and other cultural practices which tend to reduce top growth. Rainfall in this location is quite heavy from October to February, which coincides reasonably well with the lifting and shipping season. This is less objectionable than during the growing season. (See appendix for more detailed climatological records.)

Temperatures in February to April appear to be near optimum for prompt germination. This is very important because tender young seedlings are subject to a host of diseases and insects. Conversely, high temperatures inhibit germination and often result in a partial stand unless the seedbeds are shaded. Artificial shading should be avoided if possible because it creates additional cost.

Site Preparation

A plan for the layout of the nursery is shown in figure 4. About half of the ammunition shelters should be removed, along with the trees, to permit an effective and efficient bed arrangement. The remainder need not be disturbed; in fact, one--or possible two--can be modified for cold storage of seedlings. Presumably these are well reinforced with steel and would require cutting-torch work before bulldozing when they are removed.

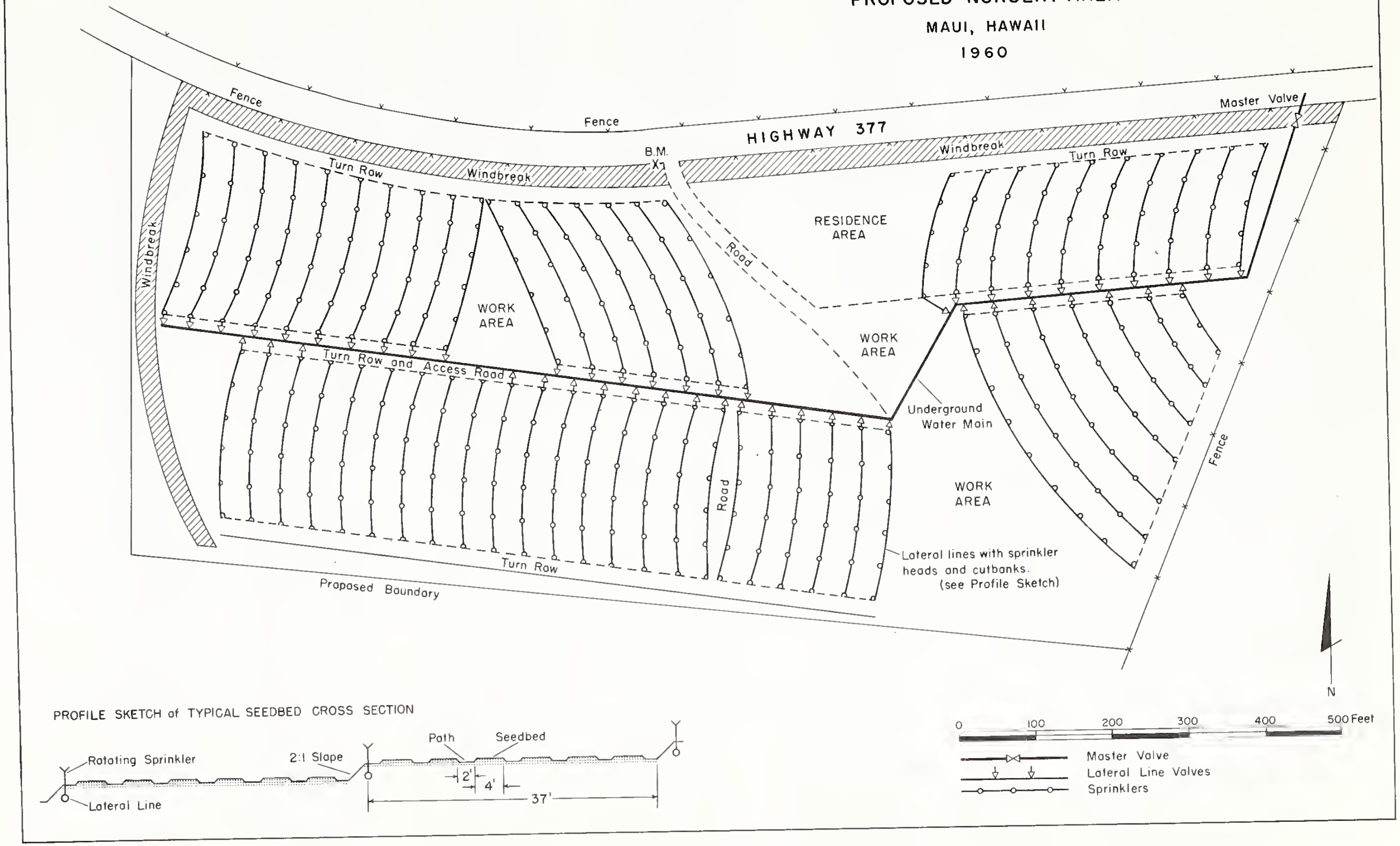
Roads leading to the shelters have been surfaced with cinders. Removal of first-size chunks by hand and scattering the balance over the entire area is expected to improve soil texture. A limited quantity of small, loose rock is present on the area. These can be hand picked when the beds are prepared.

The big job in site preparation is to remove the trees and stumps. In the seedbed areas, all stumps and roots must be removed to a depth of 16 inches. Where bench terraces are needed, virtually all of the root systems must be removed to secure the minimum depth of root-free soil under the seedbeds. The debris from the trees, stumps, and roots must not be burned on the areas where seedbeds or shelterbelts are to be established because excessive heating would destroy the structure of the soil. Preferably, the debris should be removed from the site, but if this is impractical, it may be burned on the work area.

The entire area need not be cleared at the present time. Initially, 2 or 3 acres can be prepared. As additional seedbeds are required, clearing can be extended. Such a program would, of course, require detailed plans for both immediate and future needs.

When fully developed, the selected Maui site would be capable of producing between 5 and 8 million seedlings annually. The range in capacity is due to the difference in the number of seedlings grown per unit of area for conifers and hardwoods. The proportion of pine to hardwood is expected to change with species requirements needed to meet approved planting plans. The immediate objective is the production of approximately 1 1/2 million coniferous trees and 3 1/2 million hardwoods.

Figure 4
SEED BED LAYOUT
PROPOSED NURSERY AREA
MAUI, HAWAII
1960



Design

The topographic and nursery layout maps (figs. 3 and 4) show existing physical conditions of the selected site and how facilities should be fitted to it to permit the use of machinery and modern techniques in all operations. To accomplish this, parallel bench terraces 40 feet in width must be constructed, following the conformation of the land as closely as possible. Each bench is curved to conform to the slope. Sharp or reverse curves were avoided because the tractor and implement attachments would cut into the seedbed shoulders as machinery passes over the seedbeds.

Cutbanks resulting from the formation of bench terraces do not exceed 18 inches in height--most are 12 inches or less. With a 2 to 1 slope ratio, erosion will not be a serious factor. A non-stoloniferous grass cover should be established on all slopes, roads, and turn rows.

It is important that each bench has a low, uniform gradient throughout its entire length to permit surface drainage to roads with a minimum amount of erosion. Low spots which remain wet and soft interfere with normal cultural operations. An excess of soil moisture, resulting from improper drainage, invariably causes erratic seedling development.

Because of the low height of the cutbanks, relatively little soil must be moved to construct the benches. This is important because of the wide difference in soil fertility between top and subsoil. Fortunately, the depth of the topsoil throughout the tract is great enough to permit some movement without serious consequences arising from differences in soil texture or fertility.

The typical profile diagram (fig. 4) shows the arrangement of terrace benches, seedbeds, and irrigation system. Each bench has 6 seedbeds and 7 paths which occupy 37 feet, thus placing irrigation lines at 40-foot intervals. Since each line distributes water 40 feet on each side, lines must be spaced uniformly throughout a block of seedbeds.

Rotating sprinkler heads are spaced at intervals of approximately 40 feet on all lines. Owing to variation in the length of the beds, the sprinkler heads cannot be spaced at exactly 40 foot intervals. Sprinkler head spacing varies from 37 to 43 feet, depending upon the actual length of the line. This slight variation in spacing would have no material effect on the uniformity of distribution of water over the seedbed area.

Nozzle diameter of the rotating sprinklers must be small in order to secure minimum droplet size. It is recommended that sprinklers be comparable to Rain Bird No. 29--1/8 inch nozzle operating with water pressure between 35 and 40 pounds per square inch. With these

specifications, the discharge rate will be 2.87 gallons per minute per sprinkler head or 0.18 inch per hour. Sprinklers along roads and on outside lines should be adjustable, part circle design, similar to Rain Bird No. 35 with 1/8 inch nozzle.

The diameter of the main pipeline should be not less than 3 inches, which will permit the operation of 3 to 5 lateral lines at one time. Lateral line sizes should vary according to the number of sprinkler heads and length of line. Those under 200 feet in length should be at least 1 1/4 inch in diameter. Longer lines will be combinations of 1 1/2 inch and 1 1/4 inch sections. All pipe lines are slightly in excess of minimum sizes needed to deliver the quantity of water needed. Depositing of dissolved solids in pipes is definitely a factor on Maui and allowance for this has been made in pipe specifications.

Permanent lateral lines should be installed in lieu of any portable system. The spacing of sprinkler heads varies somewhat for each block. Thus the moving of lateral lines from one section or block to another would entail repeated adjustment. Moreover, intermittent irrigation of all seedbed areas is essential because beds not in trees are sown to soil-building crops preparatory to subsequent tree crops.

A water storage tank with a minimum capacity of 20,000 gallons is recommended. It would be located north of Road 377, high enough above the nursery to secure a gravity working pressure of 40 pounds per square inch at the sprinkler heads. A steel tank rather than a wood stave tank is preferred since it may be necessary to use all water available for extended periods.

A supply pipeline must be run from the Olinda main because of the overload on the Makawao line nearby. It will require approximately 14,000 feet of 2-inch line terminating at the reservoir. Because time restrictions--but not quantity--as to water usage are in effect in this section of Maui, it was necessary to increase the supply pipe size in order to have ample water within the time allowances when the nursery is operating at maximum capacity.

Windbreaks are necessary on the north and west sides of the nursery. The present stand of trees along the road can be used as a start but will need supplemental planting to make it more effective. Establishment of a windbreak on the west is suggested as additional protection from the trade winds. Velocities at the nursery site are normally quite low but occasionally might increase enough to damage unprotected seedbeds.

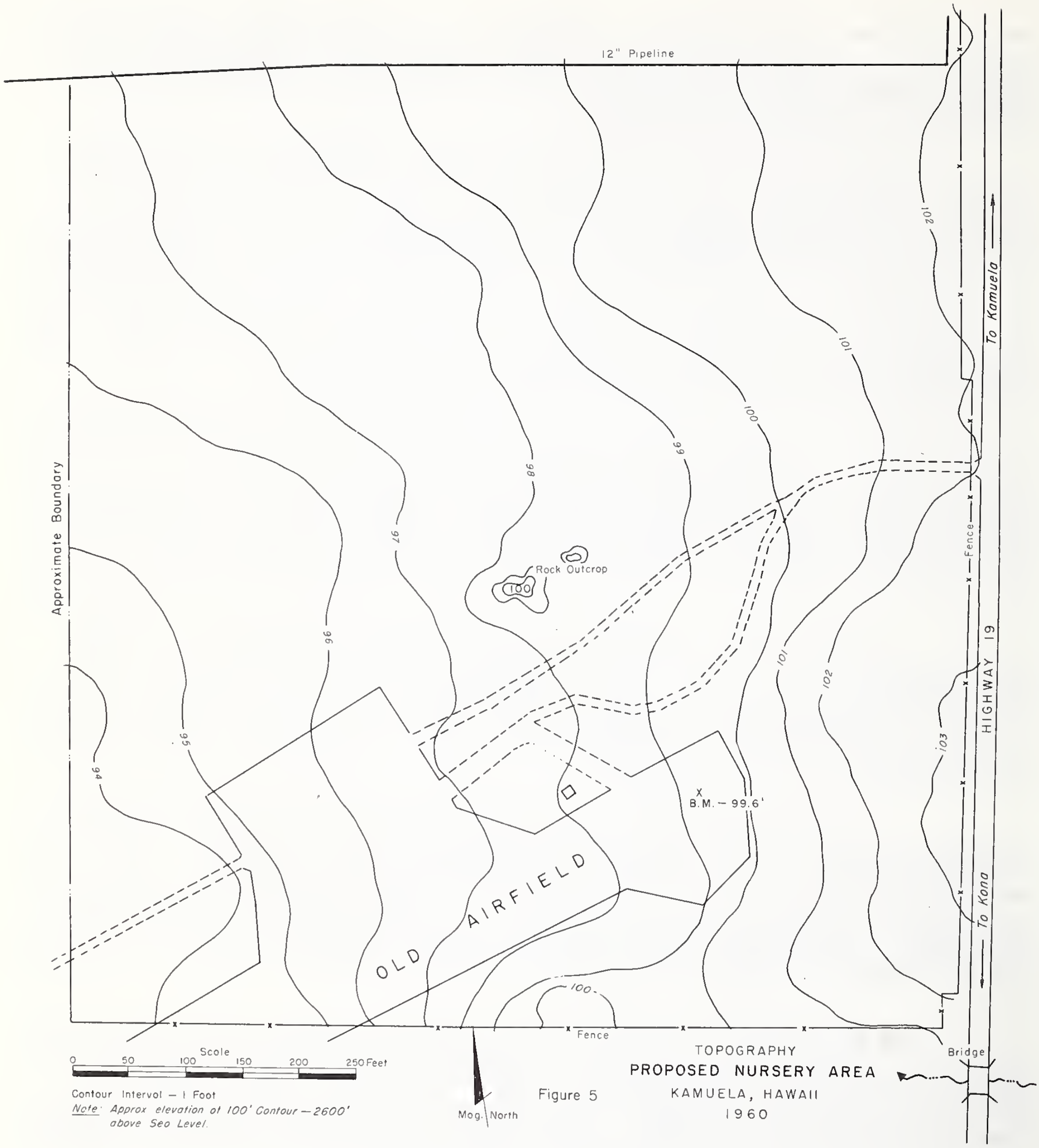


Figure 5

TOPOGRAPHY
PROPOSED NURSERY AREA
KAMUELA, HAWAII
1960

SECTION III

The Big Island Site

A tract designated as Block 8 of the Lalamilo Project, near Kamuela on the Island of Hawaii, meets minimum requirements for a nursery. It contains 15.3 acres (gross) including a road right-of-way along the north boundary and rock outcrops in the southeast corner which cannot be used for nursery purposes.

Physical Conditions

The topography is very favorable for a nursery; gradient is less than 2 percent and uniform throughout (fig. 5). The soil is mapped as a Waimea fine sandy to silt loam, derived from volcanic ash under semi-arid conditions. Depths range from 18 inches to 3 feet or more to bedrock. Both A and B horizons are very friable. Subsoil is medium textured with a weak subangular blocky structure. The soil is well drained and has a permeability factor in excess of 2.5 inches per hour. Water holding capacity is rated as moderate.

Waimea soils are considered fertile with a pH of 6.2 - 6.8 in the A horizon and only slightly higher in the subsoil. Chemically, the soil is high in potassium and calcium. Phosphorous level varies widely but no serious problems are encountered in phosphate fixation commonly found in other soil groups. Level to gently rolling phases are used for truck farming. Numerous adjacent farms are located on similar soils.

Recommended site for nursery near airport at Kamuela, Hawaii. Old asphalt landing strip and rocks in soil must be removed; windbreaks must be planted. In other respects this site appears to be very satisfactory.

Loose rock, varying in size from small to large boulders, is found throughout the soil profile. Their removal to a depth of 12 to 15 inches is prerequisite to any nursery operations.

Climate

The area is located at an elevation of 2,600 feet. Rainfall varies from 20 to 30 inches annually. It is heavier from December through March than during the remainder of the year and is within the acceptable range for nursery production. Low rainfall during the growing season is a desirable feature in seedling production, since supplemental irrigation can be applied as desired for optimum growth and development. Temperature extremes and rainfall data are given in the appendix.

Strong winds are common throughout the year. Velocities are usually under 20 miles per hour but at times may exceed 35 miles per hour for short periods. All cultivated lands must be protected by windbreaks of trees and shrubs.

Site Preparation

A plan for the layout of the nursery is shown in figure 6. Part of the area once was used for an airplane landing strip and parking area. The asphalt pavement on this (22,000 square feet) must be removed, together with 2 to 3 inches of soil directly beneath which has been seriously modified by the asphalt surfacing. Replacement of excavated soil may be needed to prevent low, poorly drained spots.

All rock 2 inches in diameter and larger must be removed to a depth of at least 12 inches in the seedbed area. Only surface rock need be removed from roads, turnrows and windbreaks. Both asphalt and rock must be hauled away from the nursery area. Old roads surfaced with cinders must be levelled. Surfacing material should be scattered over the entire area and mixed with natural soil to a depth of 8 to 10 inches.

Windbreaks must be installed along the north and east boundaries and center of the tract. Both tall trees and low shrubs should be planted to form as tight a wind barrier as possible. Immediate establishment is of paramount importance to avoid wind erosion during the construction period, and to prevent serious interference with initial nursery operations. Access roads are located parallel to all windbreaks adjacent to seedbed areas. These can serve dual purposes--of providing needed roads for nursery operations and root barriers between seedbeds and windbreaks. From time to time it will be necessary to use a subsoil plow to sever roots that extend across roads to adjacent seedbed areas.

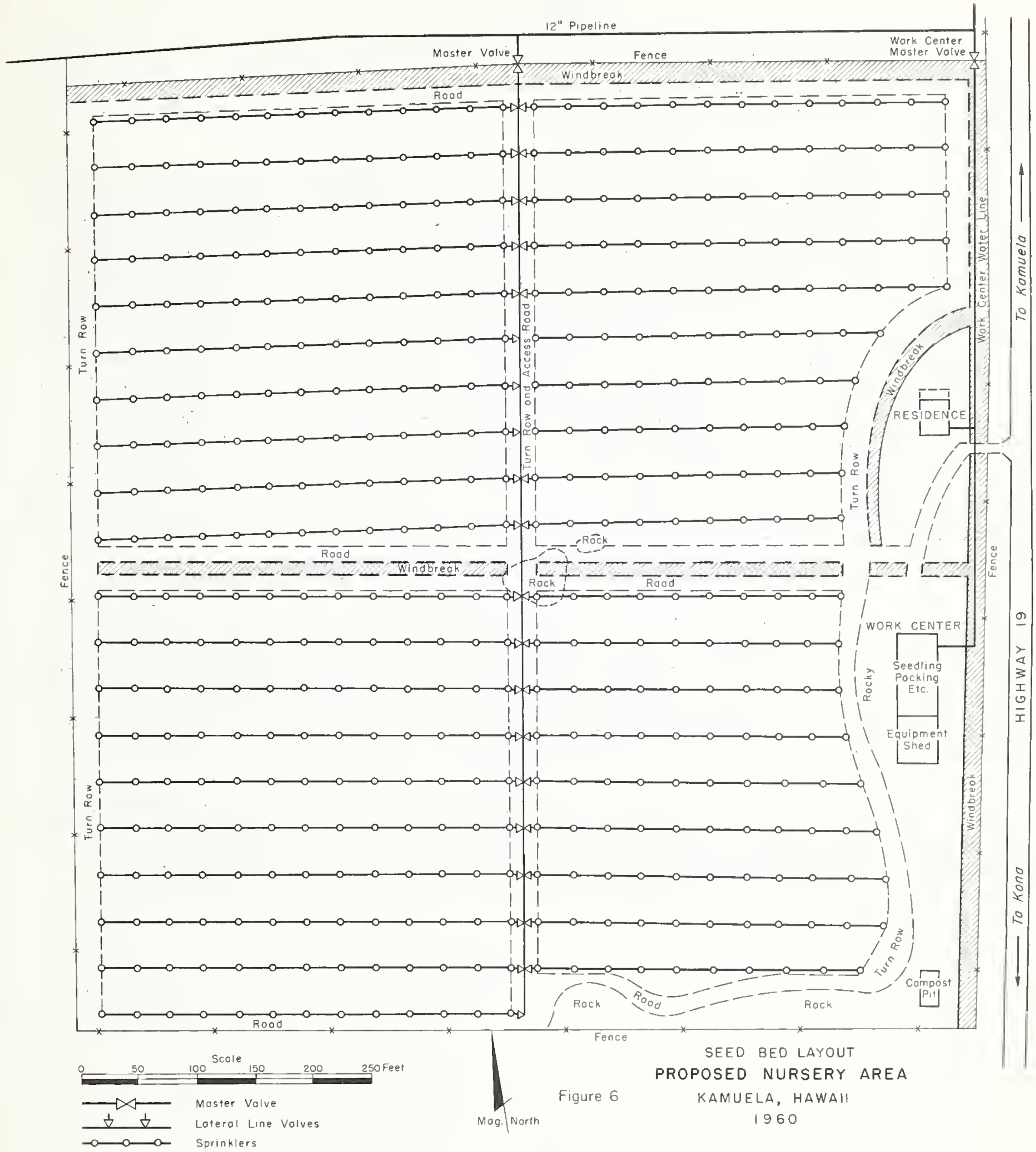


Figure 6

SEED BED LAYOUT
PROPOSED NURSERY AREA
KAMUELA, HAWAII
1960

Design

The nursery when fully developed will be capable of producing 5 to 8 million seedlings annually. The range in capacity is due to the difference in the number of seedlings grown per unit of area for conifers and hardwood.

The topographic and nursery layout maps show the physical conditions of the site and how facilities should be fitted to it. These favorable conditions permit an efficient rectangular irrigation system. One water main, bisecting the area through the center, with laterals at intervals of 40 feet requires the minimum amount of pipe. The size of the main should be not less than 5 inches in diameter in order to provide the quantity needed during peak demands. It is expected that soil movement by wind will be a problem at times, and ample water should be available to keep the surface moist during periods of high winds. Pipe sizes of lateral lines should be combinations of 2 inch, 1 1/2 inch, and 1 inch, depending on their lengths. Lines 350 feet in length will have the following pipe sizes: 2 inch 90 feet, 1 1/2 inch 180 feet, 1 inch 80 feet. Nozzle spacing on all laterals is reduced to 30 feet because close spacing is needed for proper distribution in windy areas.

It is recommended that sprinkler heads, equivalent to Rain-Bird Model No. 29, with 1/8 inch nozzle be used throughout. Greater diameter nozzles would result in large water droplets which cause sand splash damage to young seedlings. Full circle sprinkler heads are needed throughout since windbreaks must be watered at frequent intervals along with the sod cover on all roads.

Lateral line sizes have been increased slightly because of the anticipated deposition of dissolved solids after 5 to 10 years. Without such an allowance inadequate water during peak periods would necessitate expensive maintenance.

SECTION IV

Development and Operation

Nursery Equipment

A farm type tractor is the basic unit in performing many operations, from sowing tree seed to plowing, disking, and lifting. Power requirements for the heavier jobs determine the size of the tractor. The size specified is adequate for lifting operations under adverse soil conditions. A power takeoff with a wide range of speeds is essential because several different pieces of equipment are attached to it. Forward speed of the tractor must, of course, be independent of the power takeoff speeds. Other essential requirements are given in table 1.

Table 1.--Nursery improvements and equipment with estimated costs

Improvements	Haleakala Ranch, Maui	Kamuela, Hawaii
Nurseryman's residence	$ 10,000	$ 10,000
Work center building and equipment shed	10,000	12,000
Seedling cold storage room (Conversion of ammunition shelter on Maui)	2,500	6,000
Walk-in refrigerator for seed storage, 20° F. minimum	1,200	1,200
Irrigation system (on Maui includes supply line and reservoir)	22,000	17,500
Removal of present forest and ammunition shelters and terracing	10,500	0
Removal of runway surface and rocks, leveling, filling holes	0	3,000
Sub-total for improvements	$ 56,200	$ 49,700
Equipment 1/		
Pickup truck	$ 2,500	$ 2,500
1 1/2 ton truck (on hand)	--	--

(continued next page)

1/ Specific mention of a brand name is not intended as endorsement to the exclusion of other competitive models.

Table 1. --Nursery improvements and equipment with estimated costs, continued

Improvements	Haleakala Ranch, Maui	Kamuela Hawaii
Farm type tractor, Ford Series No. 901, or equivalent. Wheel spacing adjustable both front and rear, to 84 inches, tires not less than 12 inch tread; forward speeds from 1/2 to 12 miles per hour; three point hydraulic linkage with stabilizer bars, draft control, implement position control and live power takeoff with rpm speed approximating 450 at normal engine speeds. Clearance from ground to tractor not less than 29 inches	$ 4,500	$ 4,500
Two-way disk plow, with three-point hitch	475	475
Tandem disk 6' 6", with threepoint hitch	450	450
Seaman-Adwall tiller, 4-foot cut, threepoint hitch	1,100	1,100
Low pressure sprayer, tractor mounted, PTO pump, 3 section folding boom, 16 feet long; pump capacity of 5 gallons per minute, pressures from 25 to 100 pounds per square inch. Teejet nozzles No. 8001 spaced at intervals of 19 inches on boom pressure regulator and gauge, quick acting cut-off valve and necessary hose connections. All hose washers and gaskets to be neoprene rubber	300	300
Manure spreader--65 bushel capacity PTO driven	700	700
Fertilizer spreader and grain drill, 10-foot width	800	800
Tree seeder, manufactured by Whitfield Mfg. Co., Austell, Georgia	700	700

(continued next page)

Table 1. --Nursery improvements and equipment with estimated costs, continued

Improvements	Haleakala Ranch, Maui	Kamuela Hawaii
Gandy tree seeder, manufactured by E. S. Gandrud Co., Owatonna, Minn.	$ 150	$ 150
Seedbed shaper, manufactured by Whitfield Mfg. Co., Austell, Georgia	225	225
Two-wheel flatbed trailer.[2/] Local manufacture	200	200
Root pruner, 3-point hitch.[2/] Local manufacture	100	100
Seedling lifter, 3-point hitch.[2/] Local manufacture	250	250
Baling table.[2/] Local manufacture	25	25
Sand spreader.[2/] Local manufacture	300	300
Miscellaneous tools and equipment	500	500
Sub-total for equipment	$ 13,275	$13,275
Sub-total for improvements	56,200	49,700
Margin for error in estimating costs	6,000	6,000
TOTAL--Estimated Costs	$ 75,475	$68,975

2/ Blueprints are available from Regional Forester, U. S. Forest Service, Atlanta 23, Georgia.

Pressure sprayer mounted on tractor for spraying mineral spirits to control weeds. Note long boom to spray three standard seedbeds simultaneously. Photo courtesy Georgia Forestry Commission.

For efficient operation, most of the equipment, such as seedling lifters, undercutting blade, seeders, sprayer, plow, or disk harrow are attached directly to the tractor by means of a conventional three-point hitch. Several farm tractors have patented hitches which limit the choice of attachments to those normally manufactured by the tractor company. It is suggested that all attachments be designed to fit a three-point hitch which will give a wider choice of competitive farm tractors and other farm implements employed in nursery operations.

Following is a brief description of other equipment and its use:

A pickup truck is needed for routine use and in transporting supplies to the nursery. A 1 1/2 ton truck is needed for the transportation of heavier items, such as soil amendment material, sphagnum moss, etc. Transportation of packaged seedlings to distribution points will require this truck. Although not essential, a tilt platform bed is suggested as a labor saving device when handling many items.

A low-pressure sprayer is used for applying several types of chemicals to seedbeds during the growing season. These include fungicides, insecticides, herbicides, and fertilizers, all of which must be applied at a uniform rate. Repeated sprayings beginning with germination and continuing to seedling maturity are not unusual at many nurseries. Several companies manufacture competitive models. Specifications as to nozzle type and size, boom length, and arrangement of nozzles are essential points.

A two-way plow is preferred over the usual type, because it is essential that the beds be kept level and without a "dead furrow" in the center. Both moldboard or disk types are available; the disk type equipped with a threepoint hitch is best for soil conditions on the recommended sites.

A rotary cultivator is used for bed preparation and incorporating soil amendments of various kinds, particularly organic matter. This type of cultivator is widely used at forest tree nurseries on the mainland.

A manure spreader is needed to spread organic matter and seedbed cover. Certain adaptations must be made locally to permit its use over seedbeds. Wheel spacing must be changed to 72-inch centers to conform to established bed width. An auxiliary hood is added which aids in applying fine materials to seedbed surfaces but not to the paths.

A tandem disk and a combined fertilizer spreader and grain drill are needed for soil preparation and sowing green manure crops. Production of seedlings must be rotated with soil building crops which are turned under as green manure. This is a necessary part of soil maintenance and aids in preventing a buildup of fungi and other detrimental organisms common to a monocultural system of agriculture.

Two different types of tree seeders are needed to handle the wide variety of tree seed to be sown. The larger seeder described in table 1 is suitable for pine and similar types of seed; the smaller seeder for extremely small seed or seed with large wings.

Several nurserymen have developed widely different types of bed shapers to meet special soil conditions. The shaper marketed by Whitfield Manufacturing Company is about the best type for the light textured soils at the selected nursery sites.

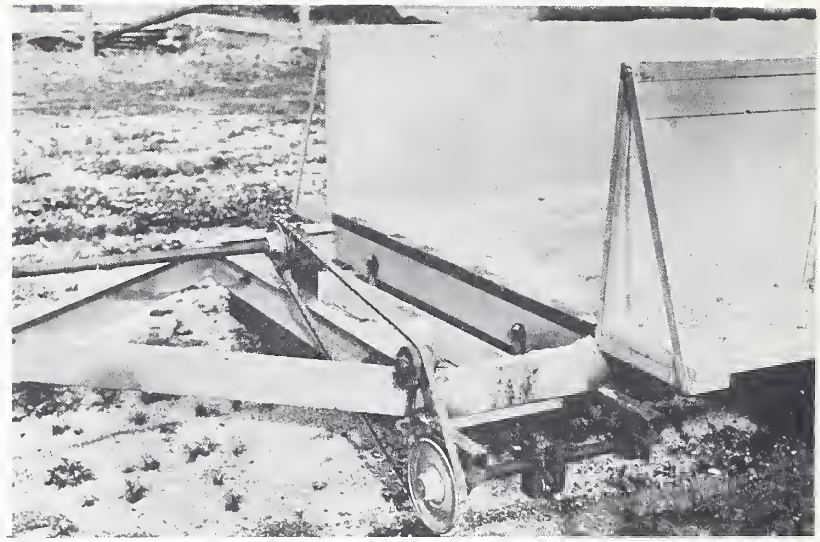
Equipment items to manufacture locally include two-wheel flatbed trailer, root pruner, seedling lifter, baling table, and sand spreaders. The trailer is for hauling lifted trees to the packing shed and for miscellaneous use around the nursery. Specific use of the other items will be explained in the section on operation of the nursery.

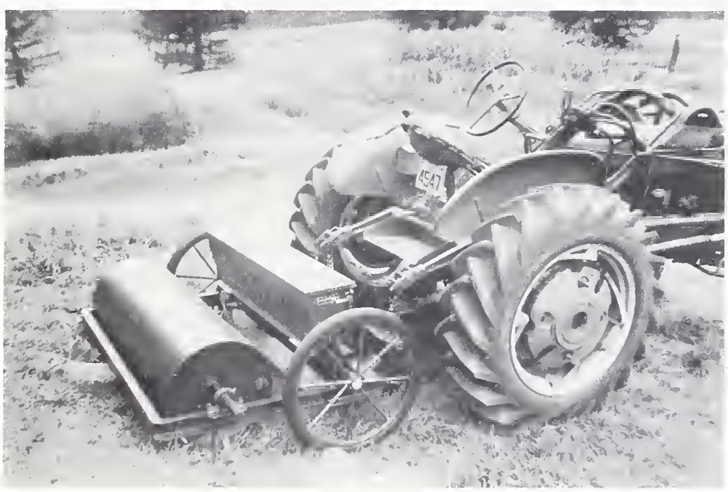
Additional facilities normally found at larger nurseries have been omitted because their cost cannot be justified in view of the comparatively small numbers of stock to be grown in Hawaii.

Buildings

Buildings included in the improvement list (table 1) are the minimum needed for efficient operation. The nurseryman's residence is necessary in order to have him live on the ground for two reasons: (1) to protect property from theft and vandalism, (2) to perform certain seasonal jobs that require attention before and after normal working hours.

Sand spreader for covering seeds. Courtesy Michigan State University, Forestry Department





Gandy seeder and roller. Courtesy New Hampshire State Nursery

A commercially manufactured root pruner with three point tractor hitch. Courtesy Rootspred, St. Petersburg, Pennsylvania

Seedbed shaper attached to a three point hitch on tractor. Southeastern United States

A combination building is recommended for seedling packing, equipment shelter, small tools, storage, and equipment repairing. In effect this building is the work center for the entire nursery. Ample space should be provided since it is difficult to enlarge when more is needed as production increases. It is suggested that the building on Maui be at least 34 feet wide and 80 feet long, half of which will be open shed space to shelter equipment. The other half should have walls and a concrete floor.

At the Maui site, one of the concrete ammunition storage buildings should be converted to a cold storage plant capable of maintaining a temperature of 34° to 40° F. Such a facility is needed as a temporary holding place for tree seedlings prior to shipping them to field planting crews. Certain tree species may be ready for lifting before planting sites are ready. The cold storage plant is desirable for keeping stock in the best possible condition for high field survival and growth. By waterproofing one of the present ammunition shelters at the Maui site, installing a cooling unit, a suitable door, and electric lights, a much needed facility will be available at low cost. At Kamuela, an entire structure must be built. Space should be provided within the work center building by making it 30 feet longer.

A small walk-in refrigerator is needed for the storage of tree seed. Virtually all of the seed used at the nursery will require dry, cold conditions for optimum storage.

Operation of the Nursery

Soil Management--Physical Properties

Good soil management is fundamental to successful nursery production. The manipulation of nutrient levels, balance, and reaction, require the addition of fertilizers, pesticides, and other chemicals. The dynamic nature of the problem demands a basic understanding of soils in relation to seedling responses.

Nursery soils must be free of rock and tillable to a depth of 12 inches because root pruners and lifting blades run at depths up to 12 inches. Texturally, the soil should approach a fine, sandy loam with good but not excessive internal drainage. Soils that are sticky or plastic when wet are not suitable. Sometimes seedlings must be lifted when the soil is wet although this is not a desirable soil management practice. It is particularly harmful in soils with a high clay content.

Poor drainage, both internal and surface, adversely affects plant growth and interferes with normal, routine cultural work. For example, applications of herbicides require careful timing, particularly during the active growing season. Delays of one to two days because of wet soil would result in seriously decreased effectiveness.

Removal of seedling roots to a depth of 10 inches without serious damage is extremely important and is directly related to soil texture. In heavy or sticky soils up to 50 percent of the fibrous root system will remain in the seedbeds. Root systems must be removed with minimum damage to insure high survival of trees when they are field planted.

Soil Management--Chemical Properties

Mineral nutrients, soil acidity, and organic content are important aspects of soil management. The mineral nutrient level of nursery soil should be maintained as high or higher than that needed for corn, cotton, and other agricultural crops. The great weight of plant tissue removed per unit of area, including both tops and roots, makes the annual drain extremely high. For optimum growth, most tree species require an acid soil ranging from pH 4.5 to 6.2. Moreover, damping off fungi are more easily controlled in acid soils than in those near or above the neutral point. Organic matter is a very important component of soil. In fact, it is the key to promoting an abundance of mycorrhizal roots, particularly on conifers.

Mycorrhizal roots result in increased growth, both in the nursery and in plantations. Maintenance of mycorrhizal fungi in the soil after their introduction should not be difficult, provided organic matter is present and other conditions are favorable. Seedling roots, well inocculated at the nursery, should be handled in such manner as to retain an abundance of these fungi when stock is lifted and outplanted.

Green manure crops, at periodic intervals, are recommended for all seedbed areas. The purpose is twofold. Continuous cropping to one type of plant permits a buildup of injurious fungi and nematodes which may be substantially checked by proper crop rotation. A second benefit comes from a better balance of plant nutrients in the soil through the use of legumes. These, when plowed under before seed ripening, add organic matter high in nitrogen which assists in decomposing other vegetation. It is not possible, however, to use green manure crops as the only source of organic matter; additional materials such as sawdust, bagasse, or chopped pineapple tops should be added before the green manure crop.

The frequency of the green manure crop will vary from 2 to 4 years, depending on the amount of organic matter present, the rate of decomposition, the soil texture, and growth responses. The new soil at the Maui site which formerly supported tree growth contains sufficient small roots to supply organic matter for two or possible three years. At Kamuela, organic matter may be needed sooner.

Periodic soil analyses, both chemical and physical, correlated with seedling responses are important tools in developing soil management practices to produce the type of stock best suited for plantation establishment. The complex nature of soils and its effect on available

plant foods preclude detailed discussion. Research in soil management must be conducted to provide answers to problems as they become apparent. Soil management through the use of fertilizers, green manure, and other soil amendments is a never-ending process.

Seed Procurement and Storage

The execution of a well organized planting program requires that the right numbers and kinds of seedlings be available to plant when needed. This in turn is contingent upon the availability of high quality seed in sufficient quantity. Some seed must be imported from the mainland or from foreign countries; some is available locally. Unfortunately, the supply fluctuates widely because of intermittent seed crops and demand. For many kinds of seed it is necessary to maintain at least a 3-year supply in cold storage. For this reason a small cold storage room is included in the list of nursery facilities. It should be capable of maintaining a low temperature of 20° F.

Strong evidence is developing through research that form, drought hardiness, limbiness, crown width, limb diameter, spiral grain, specific gravity of the wood, and growth rate are heritable. Therefore, it is important that seed be collected from stands and individual trees which have desirable growth characteristics. Through the application of genetic principles, it is entirely possible to produce trees of superior form and with other desirable attributes. Many state-operated nurseries control seed procurement by climatic zones and return the resulting seedlings to the region of origin. Pulp and paper companies frequently designate specific stands and in some instances individual trees in collecting seed for their own nurseries. Some of the larger industrial nurseries require in excess of a ton of seed annually.

A limited number of seed dealers on the mainland are known who specialize in collecting genetically superior seed and seed from designated climatic zones for several species used in Hawaii. Through close cooperation with research organizations and thoroughly reliable dealers, high quality seed can be secured for most of the species to be planted here. Seed should be collected from areas where the habitats correspond as closely as possible to those where the trees will be planted.

Without exception, records of the origin of seed should be obtained for all collections. Subsequent field plantings should retain the identity in order to determine the best source or parentage for Hawaii.

Seed extraction facilities are needed to handle local collection of both conifers and hardwoods. Specifications for such a facility should be developed when more is known of the basic requirements of the varieties to be extracted. Apparently the problem involves high seed moisture content and the rapid development of damaging molds or fungi in a very short time. Basic research may be needed on the physiology of seed before extraction specifications can be written.

Seedbed Preparation and Seeding

Seedbeds are formed with a specially designed implement attached to a tractor. A finely divided soil, free of lumps and trash, is essential. Bed surfaces must be smooth, level, and well firmed. Seed should be sown on the surface, either broadcast or in bands, depending on the species, then firmed into the soil surface by a roller attached to the seeder. A covering of black sand or sawdust 1/8 to 1/4 inch thick should then be added and firmed in place.

The quantity of seed sown per unit of area is of utmost importance. In fact, it is a primary key to successful nursery operation. Stock quality is greatly influenced by seedbed density; too low density results in oversized stock; oversowing reduces root extent and stem size. Corrective measures subsequent to germination are either impractical or expensive. It is, therefore, vital to sow the proper amount of viable seed to obtain a predetermined number of seedlings per unit of area. Optimum density varies between species. For those to be produced here, densities will range from 25 to 40 seedlings per square foot. Carefully calibrated seeders are capable of sowing precise quantities of seed.

Germination tests conducted under controlled conditions must be made for all seed lots before sowing. These tests make it possible to calculate the number of seed needed to secure the desired density. If satisfactory germination testing cannot be obtained locally, facilities for custom testing are available at U. S. Forest Service Seed Testing Laboratory, Macon, Georgia.

Time of sowing must be based on the rate of growth for each species, correlated with the time stock is needed for plantation establishment. Air temperatures at the proposed nursery sites will permit sowing from January to June and again in the fall before heavy rains. Temperature effects, both high and low, on germination and seedling establishment are well recognized factors in nursery management. Certain species require somewhat cooler weather than others; many, however, fail to respond satisfactorily at higher soil surface temperatures.

Weeding

Growth of weeds in seedbeds can be controlled in several ways, including hand methods and application of various chemicals. If seedbeds have been treated with methyl bromide to destroy nematodes and root-rotting organisms, weed population probably will be extremely low. If weeds must be controlled by other means, hand weeding is the simplest but too expensive. Most conifers are tolerant to light dosages of Stoddard's Solvent (a standard petroleum product, commonly called cleaning fluid which contains 16 percent to 18 percent of aromatic hydrocarbons). This is an effective killer for newly germinating seedlings of many common species of weeds. Care must be exercised in using this chemical to prevent injury to tree seedlings. Temperature, soil moisture,

age and condition of both conifer seedlings and weeds must be considered in prescribing the quantity to be used. Best results are secured by frequent, light, uniform applications while weeds are small. Newly germinated weeds can be killed with quantities as low as 10 to 12 gallons per acre applied two to three times per week. Older weeds may need double this amount. All applications, however, must be in keeping with the age and vigor of tree seedlings. Newly established seedlings are unaffected provided moisture is ample and seedling growth is vigorous. Dosages may be increased if necessary to kill weeds when seedlings become older. The solvent is more effective on resistant weeds if applied shortly after daylight while vegetation is covered with dew, and when there is very little wind movement.

Most species of hardwood tree seedlings are severely injured by Stoddard's Solvent. Other chemicals, such as Eptam, may be used without affecting them. This particular chemical prevents weed seed from germinating; it has no effect on established vegetation. Thus applications subsequent to tree seedling establishment eliminate repeated hand weedings for 2 to 4 months.

Irrigation

The quantity and distribution of rainfall were given careful consideration when the nursery sites were selected. Rainfall from April through October is light, heavier rainfall coming during the winter months when most seedlings will be lifted and outplanted.

The application of supplemental water, both as to the time and amount, must be correlated with seedling development. This is especially true with mild temperatures from February to mid-November. Occasional unseasonable warm periods may occur any time during the winter months. Insofar as possible, soil moisture must be kept low as stock approaches plantable size. In effect, water should be used as a growth regulator.

Physiological as well as morphological characteristics are influenced sharply by soil moisture. Woody tissue develops more readily where moisture tension is high. Thus by withholding moisture at the proper time stock quality can be improved.

Diseases and Insects

Parasitic nematodes and harmful fungi occur normally in virtually all nursery soils. Preliminary tests show that soil fumigation should be a routine practice in tree nurseries in the Hawaiian Islands. The problem, however, is complicated by the presence of mycorrhizal fungi which are beneficial to tree growth both in the nursery and in forest plantations. Mycorrhizal fungi will be destroyed unless fumigants are applied skillfully under rather rigid limitations as to soil moisture, texture, organic matter, air temperature, and quantity of chemical applied. Organic matter in process of decomposition appears to retain viable mycorrhizae-forming fungi in sufficient quantities to inoculate

subsequent seedling crops. Application of methyl bromide at the rate of 1 pound per 100 to 150 square feet under polyethelene covers for 24 hours is recommended. This is a standard practice in many nurseries elsewhere having similar soil texture. Heavier dosages destroy a greater variety of soil organisms, including those classed as beneficial.

Soil fumigation has two side effects which must be considered. First, it makes nitrogen more readily available to plants and thus when soil moisture is ample causes plants to grow excessively. Usually the response is confined to the first crop of trees and decreases with subsequent treatments. Soil management practices must, therefore, take into account the effects of methyl bromide on availability of nitrogen. Second, fumigation kills weed seed present in the soil. This effect lasts 2 to 4 years.

Leaf blights do not appear to be serious problems at the recommended sites at the present time. Several effective fungicides are available which can be applied in solution using the power sprayer.

Insects, such as cutworms and several leaf eaters can be controlled by spraying with emulsions of chlordane, parathion, malathion, dieldrin, or other appropriate chemicals when insects are vulnerable. Some chemicals remain in the soil for extended periods before breaking down. Excessive applications can result in an accumulation high enough to kill both tree seedlings and cover crops. The nurseryman should keep informed about developments in the field of pesticides and the direct and indirect effects of these chemicals.

Numerous nursery techniques can be used to produce high quality stock. These vary by species, growth habits, and physical conditions. Top pruning, for example, can be done on certain coniferous species to obtain better root-to-shoot balance. Top pruning hardwoods is a widely accepted practice. A few species may respond unfavorably.

Root pruning to promote more lateral and fibrous roots is becoming standard treatment, particularly for conifers. Species formerly transplanted to secure greater root extent are now undercut in seedbeds when sown to proper density. Most pines, including slash, longleaf, loblolly, shortleaf, and ponderosa, benefit from root pruning; top growth is more uniform and root development is improved. Deep-rooted hardwoods, particularly those with long, heavy tap roots, are often undercut. Severing roots at 8 to 12 inches one to two months before lifting permits callus tissue to form and more laterals to develop. Field survival and growth is improved for all species.

Root pruning must be correlated with seedling development. As a general rule it should be done before stock reaches optimum size. Top growth of taller seedlings is arrested sharply; smaller seedlings are less affected. Repeated root pruning is a practical means of controlling top growth as seedlings approach maturity. However, high soil moisture subsequent to root pruning sometimes nullifies efforts to control top growth.

Periodically, fertilizer must be applied either in solution or granular form as deficiencies become apparent. The effects of such nutritional deficiencies vary with soil conditions, species, and age of stock. They require a wide range of treatments. Unfortunately different deficiencies sometimes result in identical symptoms in foliage color, growth rate, and other characteristics. Only through experience can the nurseryman become adept in diagnosing most troubles; complicated situations sometimes require extensive research before corrective measures can be applied.

Stock Distribution

Removing seedlings from seedbeds, grading, and packaging for shipment to field planting crews are critical operations. One of the nurseryman's greatest responsibilities is to deliver fresh, high quality seedlings, capable of survival and rapid growth when outplanted. Careless lifting strips off most of the fibrous rootlets. Inadequate protection of roots from drying winds will cause serious mortality. Stock packed with insufficient wet moss arrives at the planting site either completely dead or severely weakened. Heating in transit can occur when stock is exposed to high temperatures.

Unfortunately, mishandling in any specific operation cannot be pinpointed as the cause of mortality. Moreover, the effects are cumulative. Some exposure at lifting time, for example, may not affect survival materially, provided no additional exposure occurs. But a little drying at each step in packing, shipping, and field planting may be enough to cause serious mortality. Improper handling at any or all stages contributes to poor stock condition.

Care must be taken in removing seedlings from seedbeds to retain most of the small fibrous roots. It is an established fact that poor survival in plantations can be the direct result of careless lifting, which leaves most of the small rootlets in the seedbed. Careful, unhurried lifting will insure an abundance of small rootlets, which are essential to initial survival and resumption of growth.

Stock should be graded and packed under shelter where it can be protected from the sun and drying winds. Wet moss should be used liberally to keep roots moist at all times. Several species may need a slurry or thin mud coating on roots as an added protection while seedlings are in transit. The slurry should be applied just before packing.

All stock should be graded to remove seedlings unsuitable for field planting. This includes those considered under minimum size or with insufficient root system or with poor top-to-root ratio. A common limit for conifers on the mainland is 1/8-inch stem caliper. Grade specifications are available for several species to be grown in Hawaii; others must be developed through research. In fact, it is not improbable that all species will need careful study to define satisfactory seedling grades for a wide variety of site conditions.

The method of packing stock preparatory to shipment varies with type of stock and climatic conditions. In Hawaii, where mild temperatures prevail, it is essential that tops be aerated to prevent heating enroute. At the same time, roots must be kept moist. This can be accomplished by using the system common in the Southern States. Seedlings are baled, using waterproof burlap as a wrapper; seedling roots overlap in the center of the bale and are kept moist with wet sphagnum moss. Wood strips are used on top and bottom of each bale to facilitate handling. Bales weigh between 60 and 75 pounds and contain 2,000 to 3,000 plants, depending on their size.

Stock well chilled in the nursery cold storage plant before shipment should arrive at the planting site in good condition. Bales may be kept intact for 2 to 3 weeks, if water is added as needed to maintain the moss in a thoroughly saturated condition. Baled stock stored in a cool place for a month has survived better in planting experiments than trees that had been trenched-in for the same length of time.

Estimated Costs

Some thought has been given to the operating cost of the proposed nursery. The cost of procuring seed and some supplies and specialized items will be higher than for nurseries on the mainland. Water used in irrigation probably will be more costly, and electricity, gasoline, and oil likewise are more expensive.

Modern grading and packing tables facilitate rapid handling of large quantities of stock for shipment to field planting crews.

High seed costs are expected because only carefully selected seed should be used for all species. Collections specifically for Hawaiian use will be priced considerably higher than those for general use on the mainland but the evidence that genetic qualities and geographic strains are important factors in establishing forest stands of high quality fully justifies the increased costs in seed procurement.

Total quantity of stock produced will have a material influence on unit costs. Permanent personnel, equipment, and maintenance of facilities needed to grow small amounts could take care of considerably greater amounts with little or no appreciable increase in these fixed overhead and operating costs. Another important variable relating to average estimates arises from the inherent cost differential of the species to be produced. Specific quantities by species will vary from year to year, consequently only a general price range can be cited.

Based on a minimum production of 4 1/2 million seedlings, direct costs should be between \$10 and \$15 per thousand on Maui and about 10 to 20 percent more or \$11 to \$18 on Hawaii. This includes commercial air transportation to other islands. It does not include indirect costs of the district foresters or State forester offices. Neither does it include depreciation of improvements. Reductions in unit costs can be expected with an increase in experience in operating a nursery and if production is expanded.

Costs of nursery development, permanent improvements, and nursery equipment are given in table 1. For Maui they total \$75,475 and for the Big Island \$68,975.

Keeping Informed on Nursery Practices

Nursery management requires continuous study and review by those in charge. Current nursery plans must be modified to meet changing conditions. New ideas for improvements should be expected to come from several sources. First, the nurseryman through his day-to-day duties should become increasingly expert at solving his local problems. Second, the nurseryman should be encouraged and assisted to attend conferences of nurserymen on the mainland and elsewhere. Each year, several group training meetings are held by nurserymen in the major forest regions of the United States. An occasional trip to forest tree nurseries in tropical and sub-tropical areas probably would be rewarding in new ideas and better methods.

Review of technical literature is another way to learn about scientific and technological advances in nursery practice. A study of current literature should include, in addition to well known forestry serials, such as Tree Planters Notes, Journal of Forestry, and Unasylva, specialized publications on insects, diseases, and soil management.

The services offered by scientific and research organizations should be used to the fullest extent. Contact should be maintained with the University of Hawaii, federal and state forest and agricultural experiment stations, and local research institutions such as the Pineapple Research Institute and the Sugar Planters Association.

APPENDIX

Rainfall and Temperature Data

Rainfall and temperature data are not available at the immediate site of the proposed nursery site on Maui. The nearest weather station is at the Haleakala Branch Experiment Station, University of Hawaii, near Makawao (see table, next page). Temperatures closely approximate those at the nursery site, but the rainfall at the site is known to be somewhat lower. These data show trends and patterns rather than precise quantities at the proposed nursery site.

Median rainfall data are used since they express rainfall most likely to be expected and are preferred over arithmetic averages. Monthly rainfall data are not available on the same basis; arithmetic means are given to show the general distribution pattern.

Rainfall and air temperatures at Haleakala Branch Experiment Station (Station No. 434.1)

Annual Rainfall Pattern 1/
(inches)

Maximum	Upper Quartile	Median	Lower Quartile	Minimum
92.6	67.4	57.7	38.4	23.7

Monthly Rainfall 1/
(inches)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Max.	26.4	23.1	26.3	20.2	7.2	11.4	6.2	11.3	2.8	16.2	12.7	27.6	
Med.	5.1	4.9	8.2	4.8	2.8	0.8	1.7	1.7	0.8	2.7	3.0	5.7	42.2
Min.	0.1	1.2	0.6	0.6	T	0.0	0.0	0.1	0.0	0.1	0.9	1.7	

Monthly Temperatures 2/
(degrees Fahrenheit)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Annual
Mean max.	70.4	70.7	70.3	70.6	74.8	74.7	75.2	75.9	76.0	74.6	72.8	70.0	
Mean min.	53.9	55.6	56.7	57.6	58.5	60.9	62.1	62.6	61.4	61.1	59.1	57.8	
Mean	64.0	61.9	64.5	64.0	65.4	68.3	68.5	69.6	69.8	68.3	66.7	63.1	66.2

1/ Nineteen year record from Rainfall of the Hawaiian Islands, Hawaii Water Authority, September 1951.
2/ U. S. Dept. of Commerce, Climatological Data, Annual Summary, 1959. Vol. LV No. 13.

Rainfall and air temperatures at Kamuela (Station No. 192.2, Hawaii)

Annual Rainfall Pattern[1/]
(inches)

Maximum	Upper Quartile	Median	Lower Quartile	Minimum
58.6	35.5	28.6	22.4	14.9

Monthly Rainfall[1/]
(inches)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Max.	9.2	12.6	11.4	8.6	4.4	3.5	3.5	6.4	1.6	5.8	6.9	13.3	
Med.	3.9	2.6	3.2	2.4	1.7	1.3	1.5	1.4	0.7	1.4	1.9	2.6	24.6
Min.	0.4	0.2	0.5	0.6	0.5	0.3	0.3	0.5	0.2	0.4	T	0.8	

Monthly Temperatures[2/]
(degrees Fahrenheit)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean Annual
Mean max.	73.3	73.0	72.3	72.8	74.0	74.7	75.0	76.0	77.5	77.5	75.5	73.3	
Mean min.	52.5	52.4	52.5	53.3	54.4	55.2	54.3	56.9	56.8	56.2	55.0	53.6	
Mean	62.9	62.7	62.4	63.1	64.2	64.9	64.6	66.5	67.2	66.8	65.2	63.4	64.5

1/ Forty nine year record from Rainfall of the Hawaiian Islands, Hawaii Water Authority, 1959.
2/ U. S. Dept. of Commerce, Climatological Data, Annual Summary, 1959. Vol. LV No. 13.